Evaluation of Implementation and Effectiveness of a Pilot Multi-Domain Program for Older Adults at Risk of Cognitive Impairment at Neighborhood Senior Centres – A Randomized Controlled Trial

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Abstract

Background The efficacy of multi-domain interventions for dementia prevention has been investigated in a few large randomized controlled trials (RCT). To link research to community action, we evaluated the implementation and effectiveness of a community-based multi-domain program for older adults at risk of cognitive impairment.

Methods Three enterprises implemented a 24-week, bi-weekly, multi-domain program for older adults at risk of cognitive impairment through neighborhood senior centres (SCs). The program comprised a combination of dual-task group physical exercise, pen-and-paper cognitive games, computerised cognitive training, and mobile application-based personalized nutritional guidance. An effectiveness-implementation hybrid design using a RCT design and informed by the RE-AIM (Reach, Effectiveness, Adoption, Implementation, Maintenance) framework was adopted to evaluate the program. Cognition and quality of life were assessed using the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS), and EuroQol EQ-5D-5L (EQ-5D) respectively, at baseline and 24-weeks. Blood lipid panel and physical assessments were also conducted. Questionnaires on implementation outcomes were administered at the participants-, provider- and community-levels to participants, implementers, and SC managers. Program schedules and attendance were obtained from implementers and the research team conducted unannounced, random and non-intrusive observations of the program.

Results The intervention program reached almost 50% of eligible participants, had an attrition rate of 22%, and was adopted by 8.7% of the SCs approached. The intervention was implemented as intended, except the nutritional component that was re-designed due to participants' unfamiliarity with the application. There were no between-group differences in cognition, quality of life, and blood lipid panel, though there was a reduction in quality of life in the control group and improved physical function in the intervention group at 24-weeks. Intervention group participants reported improvement in their physical and cognitive functions. The program was well-received by participants and centre managers, who wanted the intervention to continue post-study.

Conclusions A six-month multi-domain program for older adults at risk of cognitive impairment can be implemented through neighborhood SCs and elicit improvement in physical but not cognitive performance. Implementation evaluation highlight areas to improve on the uptake of such community-based interventions.

Trial registration Trial registration: ClinicalTrials.gov NCT04440969. Registered 22 June 2020 - Retrospectively registered, https://clinicaltrials.gov/ct2/show/NCT04440969

Contributions To The Literature:

- Studies on multi-domain interventions for dementia prevention have focused mainly on individual-level health-related outcomes; there is a lack of implementation and client outcomes for research translation.

- We evaluated the implementation of a community-based multi-domain program for older adults at risk of cognitive impairment, and report the implementation and effectiveness outcomes to inform research translation.
- Our findings on program implementation and client outcomes can be applied to narrow the know-do gap through improving on and scaling up of a community implementation model.

Introduction

The efficacy of large multi-domain interventions for dementia prevention, which include varying combinations of diet and/or medication, physical and cognitive exercises and other lifestyle modifications, have been widely discussed. In recent years, three large European randomized controlled trials (RCTs) namely the Finnish Geriatric Intervention Study to Prevent Cognitive Impairment and Disability (FINGER) (1), the Multidomain Alzheimer Preventive Trial (MAPT) (2) and the Dutch Prevention of Dementia by Intensive Vascular Care (preDIVA) (3) which employed multi-domain interventions for dementia prevention have been conducted. Only the FINGER study of 2-year multi-domain intervention showed improvement or maintained cognitive function in older adults at risk of dementia. Additionally, a National Academies of Sciences, Engineering, and Medicine review reported some degree of support for the benefit of three classes of intervention: cognitive training, blood pressure management in people with hypertension, and increased physical activity (4).

So far, no study has examined the factors that support the implementation of these multi-domain interventions. This lack of information on implementation methods impedes the research translation of effective interventions (5, 6). Evaluation studies that investigate the implementation are critical to consider acceptability, adoption, effectiveness, scalability and sustainability of the intervention in actual community settings (7). Furthermore, comprehensive evaluation can help in determining the public health impact of interventions, aiding policy decision on resource allocation (5, 6).

In Singapore, the prevalence of dementia is about 10% amongst individuals aged 60 years and above (8). With a rapidly ageing population (9), dementia is an issue that Singapore directs national attention to. In 2016, the Health Ministry issued a National Innovation Challenge to fund pilot implementation of scalable preventive intervention programs that can be used safely to improve cognitive functioning in older adults (10).

In response to the challenge, this pilot project was conducted using a hybrid implementation-effectiveness design (11) that concurrently 1) evaluated the implementation and 2) assessed the effectiveness of a multi-domain dementia-prevention intervention program among community-dwelling adults at risk for mild cognitive impairment and dementia in Singapore. Under the auspices of the national challenge, the Geriatric Education and Research Institute (GERI) team adapted the multi-domain intervention from the FINGER study and partnered business and community service providers to implement it at neighborhood senior centres (SCs). The RE-AIM framework (Reach, Effectiveness,

Adoption, Implementation, and Maintenance) guided our evaluation (12). This paper presents the findings of the study and discusses the program effectiveness and implementation.

Methods

Study design

The study consists of a 24-week program delivered to participants randomized into an intervention (IG) or wait-list control group (CG). The IG participated in the program from 0 to 24 weeks while the CG continued with their usual routine. After the IG concluded their 24-week program and both groups completed post-program assessments, the CG also received the same program for ethical reasons.

Randomization was performed following simple randomization procedures (computerized random numbers) by a statistician who had no contact with participants. Participants and study assessors were blinded to their groupings.

The study obtained ethics approval from the National Healthcare Group Population Study Domain Review Board.

Participants

Sample size was calculated based on the recommendation by Billingham on the minimum number of participants required for a pilot trial (13). Taking a 50% attrition rate into consideration, a minimum of 100 participants per study arm was calculated as required for statistical significance between groups.

Participants were community-dwelling older adults aged 55 years and above at risk for cognitive impairment. A predictive model for risk of cognitive impairment was developed using data from the Singapore Longitudinal Ageing Study (SLAS) and translated into a risk scoring tool that comprises seven factors - age, gender, education level, history of depression, satisfaction in life, hearing and presence of metabolic diseases such as diabetes, abdominal obesity, hypertension or abnormal blood lipid levels (see Additional File 1) (unpublished data). The model provided a percentage estimate of a person's risk of developing cognitive impairment over Y years (see Additional File 2). Older adults who scored 6 or more out of the total possible 16 points were invited to participate in the study. A risk score of more than 6 translated to a 10% risk of developing cognitive impairment over the next five years. Participants who were excluded from the study were those diagnosed with cognitive disorders including mild cognitive impairment, dementia or Parkinson's Disease, were wheelchair bound, had total hearing or visual impairment, or had medical instructions prohibiting their participation in the program.

Setting

Participants were screened and recruited from senior activity centres (SACs) and senior care centres (SCCs) in Singapore. SACs are located within residential estates and provide government subsidized space and activities for older adults to socialize with peers. Besides conducting social recreational activities such as karaoke, arts and exercise sessions to maintain health and engagement, SACs also provide support services such as befriending, emergency alert response calls, referrals and home visits. SACs in certain estates serve mainly low-income older adults living alone. SCCs are integrated care support centers that provide social daycare, dementia daycare, nursing and rehabilitation services to eligible older adults (14). Potential participants were introduced to the program through an introductory talk conducted at various SACs and SCCs that included topics about healthy living and eating. Interested parties were then screened for eligibility using the risk score. For conciseness, both SACs and SCCs will be described collectively as senior centers (SCs) henceforth.

Intervention Program

A bi-weekly program comprising cognitive training, physical-cognitive dual-task exercises and nutritional guidance was implemented by three local enterprises. Cognitive training was delivered to participants in two forms. During the first 12 weeks, participants attended 2-hour sessions, twice a week playing cognitively stimulating games on paper-based or computerised formats. In the remaining 12 weeks, participants focused solely on playing computerised cognitive training (CCT) games. Small group activities (paper-based sessions) were designed and conducted by a trained psychologist to exercise and strengthen vital cognitive abilities such as memory, planning and executive functioning (ProAge, Singapore). Participants were placed in groups of two to three according to similar cognitive ability established via a mini test and had to complete tasks that were gamified to be relatable to daily living such as memorising ingredients for specific recipes and route planning to travel to different areas of Singapore using the public mass rapid transit (MRT) trains. The games had different levels of difficulties and progression to the next level was determined by the trainer. In the CCT games, participants wore an electroencephalogram headband (15, 16) that detects low frequency brain signals connected to a tablet while playing games that target attention, memory, decision making, spatial ability and cognitive flexibility. These CCT games also have varying levels of difficulties and participants can decide if they want to move on to a next level. A trainer was present to facilitate each session.

Physical-cognitive training of moderate intensity was conducted in supervised groups (ProAge, Singapore) over a total of 1.5-hour sessions bi-weekly. The exercises were conducted by trained fitness instructors and incorporated physical-cognitive tasks - comprising aerobic, resistance, flexibility and balance in tandem with mind-motor training utilizing memory, motor coordination and verbal fluency.

Nutritional guidance was delivered through a mobile application (17) that enabled communications with a certified dietician online. Participants were taught to download and use the application on their smartphone before the start of the intervention. Participants who had no smartphone were loaned one during program intervention. They were asked to photograph their meals (either breakfast, lunch or

dinner) daily or as often as possible and upload all photos of meals to the application. The dietician would make recommendations to improve on nutrition intake. Once a month, the dietician gave a one-hour face-to-face nutritional talk that covered various health-related topics. These talks were also accessible to participants in the waitlist control group to keep them involved in the study.

Outcome measures

Participants were assessed at baseline and 24 weeks (see Additional File 3). The primary outcome was performance on the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS) (18). RBANS assessments were conducted by assessors who were blinded to group assignments. The battery consists of 12 subtests grouped into five domains – immediate and delayed memory, visuospatial/construction, language and attention. Total RBANS scores and domain scores were standardized into T-scores.

Secondary outcomes include the EuroQol EQ-5D-5L (EQ-5D, Rotterdam, The Netherlands), which were converted into index scores (19) and reported with a self-reported health rating on the 0 to 100 Visual Analogue Scale (VAS), blood lipid panel (Cholestech LDX, Abbott, IL, U.S) and physical assessments. Physical assessments were conducted only for the IG. Questionnaires with 5-point Likert scales and open-ended questions were also conducted as part of the evaluation process. These questionnaires were administered verbally to participants, and online to implementers and centre managers. Open-ended questions such as “What kind of difficulties did you encounter when participating in the exercise sessions?” and “How do you think this program can be done differently?” allowed for the collection of free-text responses from all three groups.

Statistical analysis

Baseline characteristics of participants in the intervention and control groups were analyzed using t-tests or Wilcoxon rank sum tests for continuous variables, and χ^2 tests for categorical variables.

Independent t-tests and Wilcoxon rank sum tests were used to examine differences in cognitive, quality of life, and blood lipid panel outcomes between groups in complete case analysis. Within-group effects for cognitive, quality of life, and physical outcomes were analyzed using dependent t-tests and Wilcoxon sign rank tests. Multiple comparisons were adjusted using Bonferroni correction.

Qualitative analysis

Free-text responses were analyzed using inductive thematic analysis. Two researchers (PEMN, and SON) familiarized themselves with the text and made notes for potential codes. Potential codes were discussed until consensus on final codes. Subsequently, codes were consolidated into subthemes and then mapped into themes (20).

Evaluation

The RE-AIM framework measures used for evaluating the intervention and the data collection method employed is described in Additional File 4.

Results

Reach

Screening was performed by a study coordinator in 23 SCs, where 437 out of 672 older adults were eligible to participate. A total of 199 older adults (167 of them were females) were enrolled into the program study, with a mean age of 76.82 ± 8.97 years. Hence, the intervention reached 45.5% of the eligible population. Most of the participants (93.6%, n = 177) only had primary or no education, and 7.4% (n = 12) had at least secondary education. Mean cognitive impairment risk score of participants was 7.97 ± 1.13.

Five participants withdrew from the study before baseline assessments (reasons - family objection, inability to commit to the schedule or inability to complete the baseline assessments due to language barrier). During the assessments, RBANS was conducted in either Mandarin or English. Most participants could communicate in Mandarin, even though they may prefer Hokkien or Cantonese dialects. However, few individuals were unable to understand the assessors during parts of the test that required recall-repetition of Mandarin words. This lack of understanding was not identified in the recruitment phase; and these individuals were excluded and considered as dropouts as the rest of the program would have require this basic understanding of English or Mandarin. The remaining 194 participants were randomized into the intervention (IG, N = 96) and control groups (CG, N = 98). During the study, a further 61 participants dropped out due to medical problems, loss of interest, personal commitments such as caring for grandchildren or death (unrelated to program participation) (Fig. 1).

Effectiveness

There were no between-group differences in age, risk score, gender, education, total RBANS t-score, RBANS domains t-scores, EQ-5D index, EQ VAS, and blood lipid panel measures at baseline (Table 1).

Table 1
Baseline Characteristics of the Participants

Variable	IG		CG		p
	Mean ± SD	N	Mean ± SD	N	
Characteristic					
Age	75.61 ± 9.01	95	77.90 ± 8.84	96	.100
Gender		96		97	.705
Males	13.5%		15.5%		
Females	86.5		94.5%		
Education		97		92	.767
Below primary	92.8%		94.6%		
Above primary	7.2%		5.4%		
Risk score	7.92 ± 1.18	96	8.06 ± 1.06	97	.370
Assessment					
Total RBANS (T-scores)	51.38 ± 9.66	89	49.22 ± 10.12	94	.143
Immediate memory	51.43 ± 9.46	92	49.13 ± 9.94	96	.106
Visuospatial/constructional	50.84 ± 9.7	91	49.38 ± 10.33	95	.391
Language	51.34 ± 9.62	92	49.08 ± 10.04	96	.117
Attention	50.58 ± 10.08	92	49.62 ± 10.04	96	.498
Delayed memory					
Total cholesterol	174.7 ± 43.96	74	182.03 ± 39.42	80	.186
HDL	53.24 ± 14.18	74	56.70 ± 16.86	83	.114
LDL	99.14 ± 36.77	72	102.05 ± 35.01	79	.577
Triglycerides	118.36 ± 52.55	73	119.11 ± 57.33	81	.674
Glucose	110.15 ± 24.45	74	115.93 ± 47.34	82	.352
QoL VAS	79.39 ± 17.26	92	81.01 ± 17.47	97	.429
QoL Index	0.82 ± 0.21	93	0.83 ± 0.24	97	.319

P value indicates statistical difference between Intervention Group (IG) and Control Group (CG).

Blood test unit of measure are in mg/dL.

Between-group effects. There were no between-group differences in total RBANS score and in immediate memory, visuospatial/constructional, language, attention, and delayed memory scores after six months. There were also no between-group differences in quality of life measures and all blood parameters (See Additional File 5).

Within-group effects. There were no significant changes in total RBANS scores and immediate memory, visuospatial/constructional, language, and delayed memory scores in both the IG and CG from baseline to follow-up. The CG had significantly lower attention scores at follow-up (Median = 46.44) than at baseline (Median = 47.59), Z = 2.63, p = .0085. The CG also had significantly lower QoL VAS at follow-up (Median = 80) than at baseline (Median = 85), Z = 3.49, p = .0005, and significantly lower QoL index scores at follow-up (M = 0.78, SD = 0.29) than at baseline (M = 0.85, SD = 0.22), t = 2.54, p = .0133. LDL increased significantly in the intervention group following the intervention, Z = -2.97, p = .003, with baseline median LDL at 93 mg/dL and follow-up median LDL at 100.5 mg/dL (See Additional File 5).

Physical assessments were conducted only on the first and last session of the intervention, hence results were based on the within-group effects only for the IG. The IG improved significantly in the 2-minute steps test and both left and right handgrip strength following the intervention (Table 2).

Table 2
Physical Performance Test: Effect of the Multi-Domain Intervention Programme within the Intervention Group

Variable	N	Baseline	24 weeks	p
Steps test	57	54.47 ± 23.65	62.77 ± 27.07	.0018*
Chair stand	69	14.09 ± 5.68	16.75 ± 6.54	< .0001*
Handgrip strength (R)	74	16.36 ± 5.61	18.15 ± 5.53	< .0001*
Handgrip strength (L)	74	15.63 ± 5.31	17.02 ± 5.05	.0002*

Data presented in mean ± SD. P value indicates statistical difference within Intervention Group (IG).

From the participant questionnaire, subthemes that emerged from free-text responses included physical, cognitive, and psychosocial benefits through participation in the program. Participants felt “more toned”, had “more strength”, and “walked faster,” and did not need to take certain chronic illness medications anymore. Effectiveness of the exercises in improving physical fitness achieved a mean score of 4.21 ± 0.63. Participants felt that the cognitive games improved their alertness, allowed them to make new friends, and boosted their self-confidence. Small group activities and CCT games achieved a mean effectiveness score of 3.93 ± 0.46 and 3.97 ± 0.45, respectively (Table 3).

Table 3
Responses from IG participant questionnaire (n = 70) [maximum score of 5]

Questionnaire Items	Score
Dual-task exercise	
How often did you attend the group exercises in a month?	4.56 ± 0.82
Do you find the exercises easy to follow?	3.96 ± 0.71
Do you feel that the exercise sessions were useful in improving your physical fitness?	4.21 ± 0.63
Small group activities	
How often did you attend the games/activity session in a month?	4.60 ± 0.87
Do you find the games/activities easy to follow?	3.53 ± 0.89
Do you feel that the games/activities were useful in improving your cognition?	3.94 ± 0.46
Computerised cognitive training	
How often did you attend the cognitive classes in a month?	4.44 ± 1.00
Do you think the cognitive classes were easy to follow?	2.79 ± 0.93
Do you think the cognitive classes were useful in improving your cognition?	3.97 ± 0.46
Nutritional guidance	
How often did you use the Glycoleap handphone application in a month?	1.28 ± 0.76
Do you think the Glycoleap handphone application was user-friendly?	2.32 ± 1.28
Do you think that having a dietician was helpful in making healthier food choices?	3.27 ± 1.23
Have your eating habits changed after the programme?	3.58 ± 0.62
Data presented in mean ± SD. Questions were based on 5-point Likert scale where lower scores indicate negative responses and higher scores indicate positive responses.	

Adoption

At the centre level, during the recruitment phase which spanned over a year, recruiters contacted 103 SCs via email, of which 39 centres (38%) responded and 23 SCs were screened. Upon successful screening and consent from the SCs, the program was adopted by 9 centres (8.7%), 2 of which were formed through combining themselves with smaller affiliated centres in the vicinity. The remaining 14 SCs who had also participated in screening could not take up the program despite interest as they were unable to accommodate the study within their schedule or the lack of eligible participants to form a sizeable group – an estimate of 30 participants per centre was deemed as most sustainable and practical for training and doing group activities.

At the participant level, 77 from IG completed the intervention and both assessments and 74 from CG completed both assessments. On average, IG attendance for the dual-task physical exercises, small group activities and CCT sessions was 75.78 ± 19.13%, 78.90 ± 20.25% and 70.99 ± 23.77% respectively. Only 15% in IG used the nutritional application consistently even though participants were taught usage one-on-one. Smart phones were loaned to 4 participants who did not own one, but they were returned unused. Others who did not own phones refused to take up the loan.

SCs reported space constraint and difficulties in encouraging participation as challenges faced. Space to accommodate an average of 10 participants was required to conduct group physical exercises. Tables and chairs were also needed to conduct the cognitive exercises. However, SCs are located in the void decks of public housing flats and some (especially those in older estates) have limited indoor floor area for group physical exercises. The group exercises for larger groups are conducted outside the SAC premises. The lack of space is compounded by multiple simultaneous activities at the centres, such as board games and handicraft sessions. Most centers made phone calls to remind participants to attend classes and one made house visits to persuade participants to attend.

Implementation

All intervention components were conducted consistently by respective implementers for the study duration. Before program implementation, each SCs, implementers, and researchers agreed on schedule dates of program activities. The program comprised 48 sessions – 31% physical-cognitive dual-task exercises and 61% cognitive sessions, of which 18% were based on small group activities and 48% were CCT. Nutritional guidance was intended to be on-going via the application throughout the length of the intervention. The application also contained access to online nutritional education modules, quizzes and games that participants were free to use at their convenience.

When approval and support from management of each centre was obtained, the program was implemented within 2–3 months. The first session for all centres started within two weeks after baseline assessment. Researchers made random visits to observe the sessions and ensure that the program was conducted according to schedule and protocol.

There were no major deviations from the protocol other than the nutritional component. Due to participants' unfamiliarity with the nutritional application and IT in general, and the lack of WiFi connection at home, participation rate was very low – 86% reported that they did not use the application. Participants' free-text responses showed they had difficulties in all stages of using the application - logging in, staying logged in, taking and sending photos and conversing with the dietician via the application, or remembering the task of doing photo logs of their food.

To mitigate the low usage rate, dieticians made phone monthly calls (15–20 min) to participants to provide nutritional intervention and address participants' concerns on diet/food choice. To further engage participants, monthly nutritional health talks were conducted and extended to CG participants too.

Despite the monthly calls, some participants remained uncontactable. Only 16 (20%) participants responded to all six consultation phone calls, 42 (52%) responded to at least three calls and 61 (76%) responded to at least one call. The low answer rate can be attributed to a subtheme that emerged from participants' responses, which are difficulties due to hearing problems, phone switched off or fear of calls from strangers. The dietician also suggested that on some occasions, there was no one at home.

Other minor deviations were reported by exercise trainers who had to conduct physical assessments at the program's first session initially, resulting in the reduction of exercise time from 1 hour to less than 15 minutes, as some participants were late. However, this was not deemed to have any impact on the outcome of the data. To mitigate this, subsequent physical assessments were performed separately by GERI staff.

Implementers suggested that the lack of SCs and their own manpower introduced additional challenges to program facilitation as program was attended by many participants with mobility limitations (e.g. slow gait or could not stand for long). Implementers found that if they had to assist participants with mobility limitations (going to toilet, retrieving items needed for small group activities), other participants would be sometimes neglected, and sessions hampered. Other constraints were related to health issues. As some of the physical exercises was considered strenuous to participants with health conditions, implementers felt that the medical conditions of participants may not have been adequately screened by the SCs using PAR-Q assessment. The implementer for physical-cognitive exercise training had to make additional assessments to identify the participants with some mobility limitations that require additional attention during training.

The CCT implementer reported that tiredness and restlessness from exercise sessions prior to the CCT sessions and insufficient training time were reasons for less than optimal engagement sometimes. The lack of space in some SCs had also been cited as a constraint.

Overall, both participants and centre managers had positive feedback for trainers and for the overall program, suggesting that the program was well delivered. Participants' overall satisfaction with the program was 3.90 ± 0.80 (out of 5) and 94.2% of participants would recommend the program to their relatives and friends. Participants had positive comments for the program and trainers for all components of the program. The program was "fun" and "novel', and trainers were described as "helpful", "accommodating", "lively", "funny", and "patient". Similarly, centre managers' overall satisfaction with the program was 4.67 ± 0.47 (out of 5), and 100% of them would recommend the program to other centre managers.

The cost of the program was estimated by the implementers to be SG$620 per participant, not including the cost of manpower and a tablet needed for cognitive training. But since this was a funded RCT, the program was delivered to participants at no cost. When participants were asked how much they were willing to pay for the whole program, out of 70 who answered, 17.4% were willing to pay less than $10, 21.7% less than $50 and 7.2% less than $100. More than 50% were not willing to pay or were unsure. Reasons included being on low income support or not being able to valuate the program. As the program

was conducted in SCs, there was no cost for renting of spaces and most participants were not required to travel, other than to the centres they were already visiting almost daily.

Maintenance

At the centre level, all the centres who completed the questionnaire expressed interest to continue with the program. To date, 2 centres have approached one of the implementation partners to discuss the possibility of holding health talks for their members. There were no other enquiries or enrolment for the other components. This could be due to cost - most SCs rely on government support and private donations for operations and will have limited funds for additional activities. Five centres have yet to complete the full program due to COVID-19 related mandatory suspension of centre activities.

At the participant level, 48 out of 70 IG participants (68.5%) reported that they intended to continue doing the exercises they had learnt. Nine participants did not want to continue the program beyond the study, five only wanted to continue the exercise component of the program, and 54 wanted to continue the entire program beyond the study.

Impact of COVID-19 pandemic

The first case of COVID-19 in Singapore was confirmed on 23 Jan 2020 and the Health Ministry issued suspension of all senior centres activities on 8 Feb 2020. This resulted in the suspension of the study. The IG groups at 2 last centres had already completed 79% and 87.5% of the intervention respectively. We were able to complete these "post" intervention (considered as 24 weeks) assessments for participants of these centres within two weeks of study suspension. The suspension affected the wait-list CG participants at two centres that were into the 2nd to 4th week of the program, while the remaining 3 had not started. Decision was made to stop the study in May 2020 when the centres closure was still in force.

Discussion

In the following discussion, we summarize the key findings of our evaluation, describe the strengths of the implementation, and highlight areas of improvement in both the evaluation and implementation of the program. We also provide suggestions for future programs that can be used to promote the uptake of similar programs. While it was the right strategy to conduct the program at the SCs, reach can be increased by marketing the program more positively; perhaps as a "brain challenge" rather than a" dementia prevention" program due to the stigma of dementia for the targeted population segment. For effectiveness of the program to improve cognition, a more coordinated program of longer duration, with further adaptations/refinements of the nutrition and CCT components will require further studies.

The intervention program duration was sufficient to elicit improvement in physical but not cognitive performance. The intervention also conferred beneficial effects on quality of life of the participants. The

program was well received by participants, implementers, and community partners. Many of the IG participants, 65% of whom were above 75 years, tolerated the dual-task physical exercises well, giving a mean rating of 4.03/5 on the ease of following exercises. This could be because training was conducted in smaller groups and personalized. There is sufficient evidence that physical exercise alone can maintain cognitive function (21, 22) and quality of life (23, 24) in older adults and should continue to be encouraged.

Several studies have highlighted the beneficial effects of CCT in older adults (25–28). A recent review showed that CCT improved cognitive function of adults who are cognitively intact or mildly impaired (29). With application of technology and suitable community-based programs, new cognitive training platforms can easily be disseminated to the older population. Participants need not have IT skills to benefit from CCT (30). However, the delivery and approach of CCT applied in this study might not have been suitable for this group of participants, who, given their age and lower education levels, have not been previously exposed to tablet computer. The sudden and long exposure could have compromised on engagement despite small class sizes. IG participants' perceived report on whether CCT sessions were easy to follow was rated an average of 2.79/5, compared to the paper-based cognitive classes which achieved a mean rating of 3.53/5. Mean attendance was also lower for CCT sessions (67.6%) compared to the paper-based cognitive sessions (77.7%). In Singapore, the government recognises the potential of telehealth to deliver support and interventions and have increasingly enabled and encouraged older adults to use them (31, 32). However, as acceptance is a prerequisite to adoption (33), the type of technology applied should not only be tailored to match their needs (34) but should also be perceived to be useful and easy to use.

The challenges with technological devices also compromised the delivery of the nutritional component of the study. Participants gave low scores for the frequency and usefulness of the nutritional application (Table 3). While the application was meant to provide its users with a convenient method of gaining personalized nutritional guidance and to collect and analyze dietary data, the IG participants who tried, struggled to use it. The remaining participants either did not own smart phones, refused to be loaned one because of the fear of losing or using it or simply did not use the application. There are various factors that could have influenced the relationship between the older adults and technology. These include personal anxiety or stress and limited self-confidence, (35) and fear of misuse of technology – that the device/application might not perform as desired or might compromise their privacy. Inaccessibility issues could also be due to financial reasons or physical inaccessibility – both of which could be related to lack of support and assistance (36). Indeed, 30% of the participants in this study lived alone or with another elderly spouse and lacked social support.

Additionally, some participants found it hard to switch to healthier dietary options as they dined with family who resisted change. Others relied on food donations or could not afford healthier options. About 60.4% reported no change to their diet for the duration of the intervention. However, participants perceived the advice from the dietician as helpful, rating its usefulness an average of 3.3/5. Regular access to nutrition services will empower older adults in making healthier choices and they will benefit more from

sessions that involve active participation – such as visiting supermarkets (either actual or virtual guided tours) or hands-on meal preparation cum eat together sessions.

Temporal factors should also be considered during implementation. The larger multi-domain studies had interventions that were minimally one year (1–3) whereas this intervention duration of 6 months could be barely sufficient to elicit significant cognitive effects. Additionally, the intensity of CCT sessions in our intervention may be of moderate intensity but appeared too cognitively demanding for participants. Coupled with distractions and tiredness after the physical training, most of them found some sessions too challenging for them to try to improve on their game scores and levels. Some might also have decreased motor and visual abilities (37, 38), sensitivity to glare while interacting with screens and devices (36) or cognitive changes which are reflected in decreased perception, memory, processing speed, attention or inability to ignore irrelevant stimuli and thoughts (39, 40). It is possible that because of not fully considering these factors, insufficient time was allocated to the CCT sessions. Extra time for settling in, familiarization and orientation of tablet functions and games and frequent short breaks may be needed for these participants.

While the intervention may have reached the intended group of community dwelling older adults who are at increased risk of cognitive impairment, less than half of eligible participants agreed to participate in the study. Reasons included 1) denial of higher-risk status or the stigma of being associated with dementia, 2) reluctance to commitment to a training cum research program with additional administrative requirement (forms to read, consents to sign and procedures to follow i.e. being randomized). Furthermore, as recruitment was dependent on the active participation of older adults at their respective SCs, the program was not able to reach socially isolated adults who are at higher risk for dementia but do not participate actively at the centres. This group might benefit more from the program than older adults who are already physically, mentally and/or socially active. While there are local initiatives to reach this segment of older adults, e.g. befriending services, it is also crucial to raise public awareness of dementia and availability of stimulating programs.

Overall, the program was well received by both participants and their centres. SCs in Singapore likely need additional funding support to contract other providers to deliver targeted and effective preventive services. In our study, the centre managers facilitated the recruitment of participants and reminded them to turn up for the program and assessments. The engagement and involvement of community partners at all (the planning, pre- and post-implementation) stages are crucial towards improving effectiveness and implementation outcomes. This also facilitates accountability, ownership and may increase likelihood of continued adoption and maintenance of a program.

While our study used a variety of data sources to evaluate both the effectiveness and implementation of a community-based program and provided valuable local insights that could help bridge the research-practice gap in dementia prevention, the generalizability of results is impacted by the small sample size and lack of follow-up (partly due to COVID-19 related suspension). Another limitation is that the physical assessment was not conducted on the control group which prevented between-group comparison from

being made. Table 4 summarizes the key findings of the evaluation and areas of improvements for the program.

Table 4
Key findings of the multi-domain intervention evaluation

Key success factors	Improvement factors
• Increased out-reach to older adults through Senior Centres. • Support from centre managers enabled smooth implementation of programme. • Availability and willingness of centres to incorporate intervention into their programme schedule. • Willingness of participants to be randomised. • Programme fully implemented by three partner enterprises in the community. • Physical-cognitive dual-task exercises of moderate intensity were tolerated and enjoyed by participants with benefits to physical performance. • Small group mental activities which simulate daily living activities enjoyed by participants.	• Reaching out to target older adults (socially isolated, lesser engaged). • Temporal considerations - Adequate time for CCT factoring in frequent breaks and learning curves. - Increasing sessions on small group activities (non-technology related). - Longer intervention period i.e. > 24 weeks • Addressing technology confidence and knowledge. • Involvement of community partners in earlier stages of planning.

Conclusions

Our study employed an effectiveness-implementation hybrid design –to establish whether a multi-domain dementia prevention works and understand how to make it work in the community simultaneously. The overall positive feedback from participants, community partners, and implementers suggests that such a program can be feasibly implemented in the community. Longer term implementation research is needed to understand how to achieve more effective and sustained benefit for such a program to improve or maintain cognitive health in vulnerable older adults.

Abbreviations

CCT – Computerised cognitive training

CG – Control group

EQ-5D – EuroQol EQ-5D-5L

IG – Intervention group

MAPT – Multidomain Alzheimer Preventive Trial

MRT - Mass rapid transit

preDIVA – Dutch Prevention of Dementia by Intensive Vascular Care

RCT – Randomized controlled trial

RBANS – Repeatable Battery for the Assessment of Neuropsychological Status

RE-AIM – Reach, Effectiveness, Adoption, Implementation, and Maintenance

SAC – Senior Activity Centre

SCC – Senior Care Centre

SLAS – Singapore Longitudinal Ageing Study

VAS – Visual Analogue Scale

Declarations

Ethics approval

Ethics approval obtained from National Healthcare Group Domain-Specific Review Board Domain F.

Consent for publication

Not applicable

Trial registration

ClinicalTrials.gov NCT04440969

Availability of data and materials

The study datasets used for analyses are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

SLW, TPN, PLKY, TYY, AC and YC were involved in study concept and design. Acquisition of data was carried out by PEMN and SON. Analysis and interpretation of data was performed by PEMN, SON, SLW, TPN and PLKY. Drafting of the manuscript was performed by PEMN, SON, SLW and TPN. Critical revision of the manuscript for important intellectual content was done by SLW and TPN. All authors reviewed the results and drafts and approved the final manuscript.

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Figures

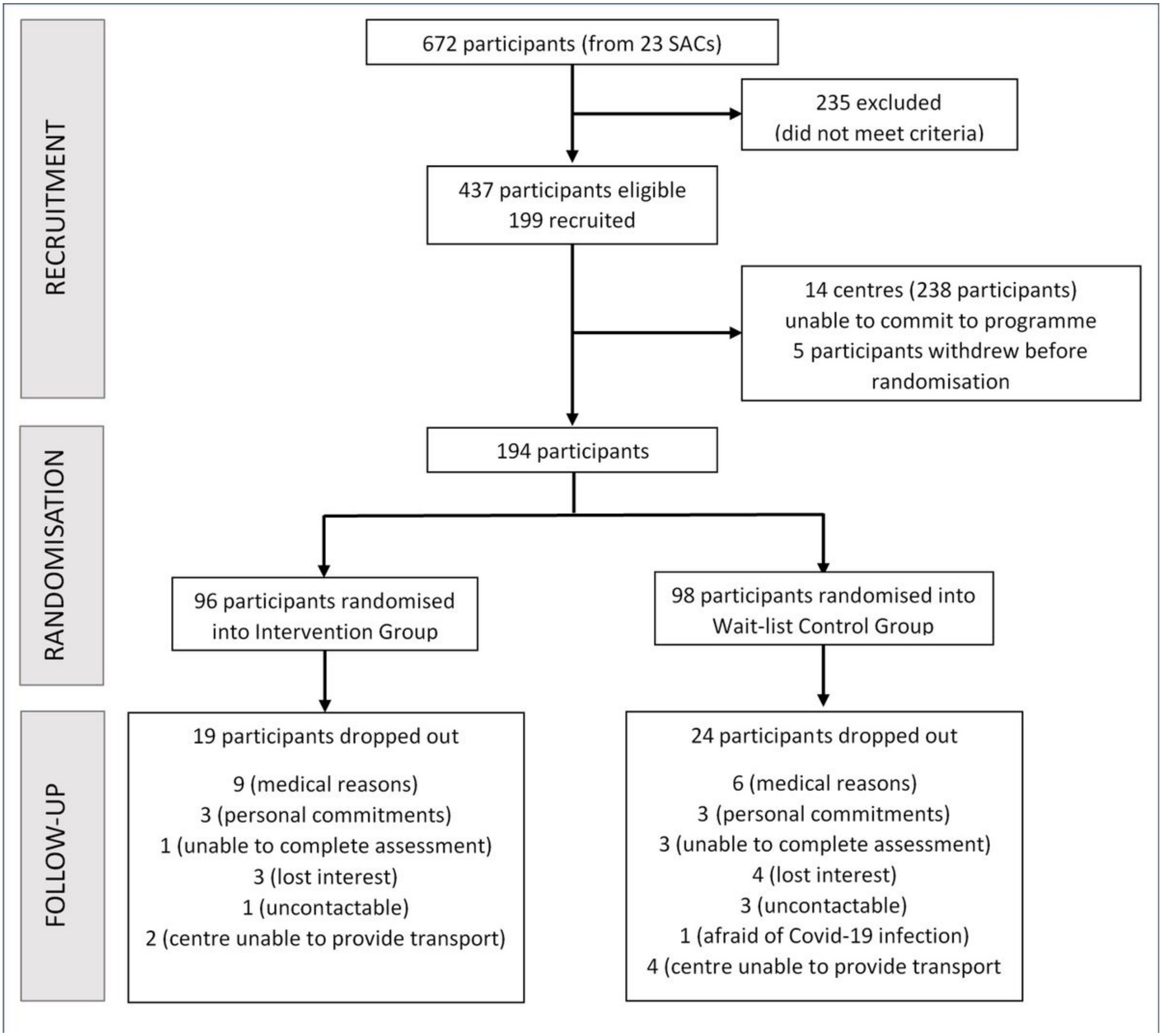

Figure 1

Participant flow diagram from initial contact to end of program.

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